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CHARL W. ERIKSEN

THE JOHNS PKINS UNIVERSITY

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PARTITIONING AND SATURATION OF THE PERCEPTUAL FIELD AND EFFICIENCY OF VISUAL SEARCH

Charles W. Eriksen

The Johns Hopkins University

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FOREWORD

This report is the result of experiments performed by Charles W. Eriksen under contract No. AF 33(038)-22642 at the Institute for Cooperative Research, The Johns Hopkins University. The contract was initiated under a project identified by Research and Development Order Nos. 694-45, Presentation of Data on Radar Scopes, and 694-43, Human Engineering Analysis of Multiple Operator Air-Ground Systems, and was administered by the Psychology Branch of the Aero Medical Laboratory, Directorate of Research, Wright Air Development Center, with Julien M. Christensen acting as Project Engineer.

ABSTRACT

The present report describes a series of experiments upon the effects of various conditions of display upon visual search. The time required to locate a constant number of signals in a square display was determined where (1) the number of irrelevant signals was varied from 10 to 70, and (2) when the number of partitions of the display was varied by the use of grid lines. Grid lines were used to partition the display into a 9 x 9, a 13 x 13, and a 16 x 16 matrix.

The results show that search time increases both when the number of irrelevant signals is increased and when the number of partitions is increased. An explanation was advanced for these effects in terms of the number of foveal fixations required for signal identification and the use that observers make of grid lines in their plan of search.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

JACK BOLLERUD
Colonel, USAF (MC)
Chief, Aero Medical Laboratory
Directorate of Research

I. INTRODUCTION

In the military setting, visual displays are used for a number of purposes varying from recognition of ground return in radar to the assimilation of information from plotting boards. Irrespective of the task, in most cases there is a need for rapid accurate identification or location of particular objects or signals in the display. The present study is concerned with certain perceptual problems involved in the visual display of information, particularly with reference to the task of visual search.

In using visual displays a common task confronting the observer is one of visual search. Here the observer is required to scan the display in order to detect the presence or location of particular signals or other encoded information. In this task the structure of characteristics of the perceptual field (display) may be expected to influence his performance. Previous research (1), for example, has shown that the heterogeneity of the field in terms of such visual dimensions as hue, form, size and brightness is a significant factor in search time. Search time, in general, was found to increase with increasing heterogeneity of the field.

In addition to heterogeneity on various dimensions a display or perceptual field can vary in terms of other characteristics. One of these is the number and different kinds of information it contains--that is, how much blank or unoccupied space there is in the display. A display may be virtually saturated with signals or the signals may be few in number and widely scattered throughout the display. Perceptually we may consider this variable as relating to the ratio of figure to ground and we might expect that the speed with which an observer can scan the display in search of specified signals would be affected by this ratio.

Displays also vary in the natural or artificial sub-divisions or partitionings that exist in them. In many displays grid lines or coordinates are used to partition the display. While these grid lines may be helpful in specifying the location of a signal, their effect upon speed and accuracy of visual search is unevaluated.

The purpose of the present experiment was to determine the effect upon visual search time of three variables, saturation, partitioning, and search area. Speed of visual search, as measured by the time it took a subject to locate a constant number of signals in a display, was determined when the following factors were varied: (1) the number of non-target signals in the display; (2) the number of partitions of the display was increased or decreased by the use of grid lines; and (3) the total area of search.

II. METHOD

Apparatus. A square display, perpendicular to the subject's line of sight, was used. The center of the display was 60 in. from the floor. It was painted a flat white in color and was ruled off into equal-sized partitions by the use of 1/16-in. black lines. A quarter-inch electrode was located at the bottom of each of the partitions and a tiny hook at the top. The number of partitions and the area of the display were varied in the experiment. A sliding panel was used to hide the display from the subject. When a catch was released, the panel dropped giving the subject a full view of the display. The dropping panel also tripped a microswitch which in turn activated an electric timer. The subject located objects in the display by touching a stylus to the electrode in the proper partition.

A control panel was mounted on the back of the display which provided connections with each of the electrodes on the face. Then telephone jacks could be plugged into these connections so as to obtain any desired pattern of ten electrodes. These jacks were connected to a system of relays, which were tripped whenever the subject touched the stylus to the corresponding electrode. When all ten relays had been tripped, in any order, they completed a circuit which stopped the timer.

The signals placed in the display were cut out of a dark grey cardboard. They were of three shapes, triangles, squares, and diamonds. All were of a constant size, 7/8-in. on their maximum vertical and horizontal dimensions. Ten triangles were always used as the target signals and the number of squares and diamonds placed in the display was varied experimentally.

Subjects. A total of 36 students at The Johns Hopkins University was used, 20 males and 16 females. No attempt was made to control for sex differences since a previous study involving a similar task (2) had shown no evidence of sex difference on this type of perceptual-motor task.

Design. The three experimental variables in this study were display saturation or the number of objects placed in the display, partitioning of the display by the use of grid lines, and the display area. For the saturation variable, the subject was required to locate the ten target objects when the display contained a total of 20, 40, 60, and 80 signals. Partitioning was varied by ruling the display off into a 9 x 9, a 13 x 13, and a 16 x 16 matrix by the use of 1/16-in. wide lines.

There are two ways in which we can vary the number of partitions in the display. One is to hold constant the area of the display as we vary the number of partitions. In this case the size of the individual partitions will vary. The other method is to hold constant the size of the individual partitions, but allow the total area of the display to vary. In the present study both methods of varying the number of partitions were used. This was accomplished by using three different display areas, 18, 24, and 32 in. square. Thus it was possible to compare differences between number of partitions when a constant-sized display was used and also when the size of the partitions in the display was kept constant.

The three experimental variables were arranged in a 3 x 4 x 3 factorial design. Twelve subjects were assigned at random to each of the three display sizes. Each subject was tested once under each of the 12 combinations of the three different partitionings and the four saturations. Within each display size, the order in which subjects were tested on the various combinations of saturations and partitioning was counterbalanced in a latin square design.

Subjects were run individually. They were instructed to locate the ten triangles in the display as rapidly as possible by touching the stylus to the electrode in the partition where the triangles were placed. In order to eliminate one source of error, subjects were instructed to count the triangles so as to be sure that they had located all ten. The subjects' score was the time required to locate the ten triangles.[1/] Search time was measured to the hundredth of a second. All subjects had received extensive practice on a similar task prior to beginning the experimental trials.

There were always ten target signals in the display. They were located among the partitions in the display according to 12 patterns. These patterns had been selected to meet the following criteria: (1) No two target signals were to be in adjacent partitions, and (2) at least one target signal was to occur in the top two rows of the display and at least one in the bottom row. Within display sizes, the 12 patterns were varied among the 12 combinations of the different numbers of partitions and saturations in a latin square different from that used for counterbalancing subjects so that no subject obtained the same pattern twice.

III. RESULTS

The search times obtained under the various treatment conditions were subjected to a modified four-way analysis of variance (saturation, partitions, display size and individuals). A summary of this analysis is shown in Table 1.[2/]

1/ Although errors were recorded they were so very rare that no analysis of them was merited.

2/ The method of analysis is identical with that described by Lindquist (4) under Plan VI. The search times were examined for evidence of skewed distributions, but they appeared from examination to be relatively normal. In view of this and also taking into consideration the report (5) that moderate departures from normality have little effect upon significance levels, it was considered unnecessary to use a logarithmic or reciprocal transformation on the time scores. Bartlett's test when applied to the data offered no basis for rejecting the null hypothesis that the variances were homogeneous.

Table 1

Summary of the Analysis of Variance

Source	Sum of Squares	d.f.	F ratio
Total	9684.1	431	
Display saturation	4267.5	3	1422.5/12.1 = 117.2**
Display partitions	579.7	2	289.9/16.7 = 17.3**
Display areas	588.5	2	294.2/61.9 = 4.8*
Subjects	2042.7	33	61.9/
Saturation x partitions	91.4	6	15.2/8.5 = 1.78
Saturation x area	47.5	6	7.9/12.1 = .65
Partition x area	14.1	4	3.5/16.7 = .21
Saturation x partitions x area	40.5	12	3.4/8.5 = .39
Within Subjects Error Terms			
Pooled subjects by saturation	1201.7	99	12.1/
Pooled subjects by partitions	1102.8	66	16.7/
Pooled subjects by saturations by partitions	1688.5	198	8.5/
Composite within subject error	3992.9	363	11.0/

** Significance beyond the .001 level

* Significance beyond the .05 level

From this table it can be seen that two of the experimental variables, saturation and partitioning, were significant beyond the .001 level of confidence, and the third variable, display area, was significant at the .05 level. However, none of the interactions between these three variables approached significance. Table 2 presents the mean search times for the various combinations of saturations and partitions for each display area. It will be noted that increasing the saturation or the number of signals in the display leads to increase in search time. Also the more the display is partitioned off by the use of grid lines, the longer is the time required for locating the target signals.

These effects can be more readily perceived graphically. In Figure 1 search time has been plotted as a function of display saturations and number of partitions. Search time has been averaged through display areas. As is apparent, search time increases monotonically as the number of non-target signals in the display increases. In fact, the function would appear to be linear, but the points are too few in number to indicate the exact shape of the function. It can also be seen from this graph that search time is less when the display has the minimum number of partitions. The 9 x 9 partitioning results in the quickest search for all saturations and the 16 x 16 the slowest. This latter effect is further illustrated in Figure 2 where search time has been plotted as a function of the number of partitions in the display and the display area.

From Figure 2 it is apparent that the relation between search time and total search area is not a monotonic one. The slowest location is obtained with the 24 in. square display. On the other hand, location is nearly as rapid with the 32 in. square as it is with the 18 in. one.

As was pointed out above, when a display is partitioned off into a greater number of areas, the size of the individual partitions or cells is decreased. It is conceivable, therefore, that the differences in search time obtained with differing numbers of partitions may be due to increasing difficulty in identifying or discriminating a signal in a smaller partition. As a check on this possibility, the three display sizes were so chosen that the partitions resulting from the 9 x 9 partitioning of the smallest display were the same size as the cells resulting from the 13 x 13 partitioning of the middle sized display and the 16 x 16 partitioning of the largest display. The failure to obtain a significant interaction between the three experimental variables indicates that the effects upon search time due to partitioning cannot be ascribed to the varying size of the individual partitions or cells in the display.

This can be clearly seen from Figure 2. If the effects upon search time due to the number of partitions was solely the result of the smaller size of the cells, it would be expected that the search time for the 9 x 9 partitioning of the 18 in. matrix, the 13 x 13 partitioning of the 24 in. matrix and the 16 x 16 partitioning of the 32 in. matrix to be approximately equal except for a slight difference resulting from differences in total search area. Comparison of these three points in Figure 2 shows that increases in search time associated with increases in the number of partitions is much greater than can be attributed to differences in the total search area or size of the display.

Table 2

Mean Search Time in Seconds for Different Saturations, Partitions and Display Area

Display Partitions	Saturation (number of objects in display) 20	40	60	80
	18 in. square display			
9 x 9	8.62	10.82	13.06	16.55
13 x 13	9.60	13.56	15.83	18.96
16 x 16	9.88	14.34	16.98	19.95
	24 in. square display			
9 x 9	11.57	13.94	16.20	19.88
13 x 13	11.86	15.91	18.06	20.55
16 x 16	12.71	16.05	20.94	22.80
	32 in. square display			
9 x 9	9.79	12.96	13.79	15.79
13 x 13	10.71	13.16	16.44	18.44
16 x 16	11.58	13.96	18.20	19.49

Figure 1. Search time as a function of display saturation and partitioning. Search time has been averaged through the three display areas and each point is the mean for 36 subjects.

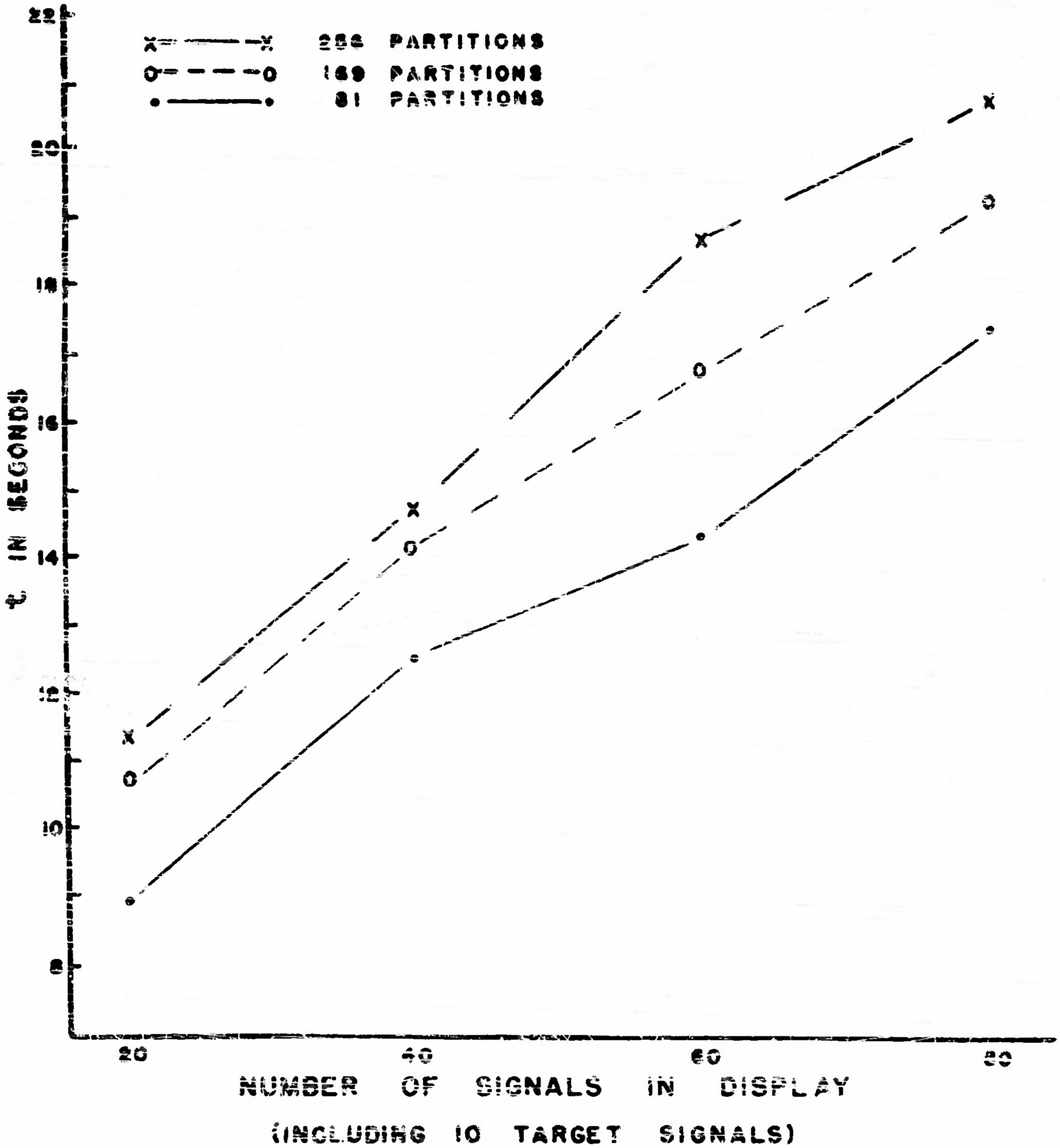
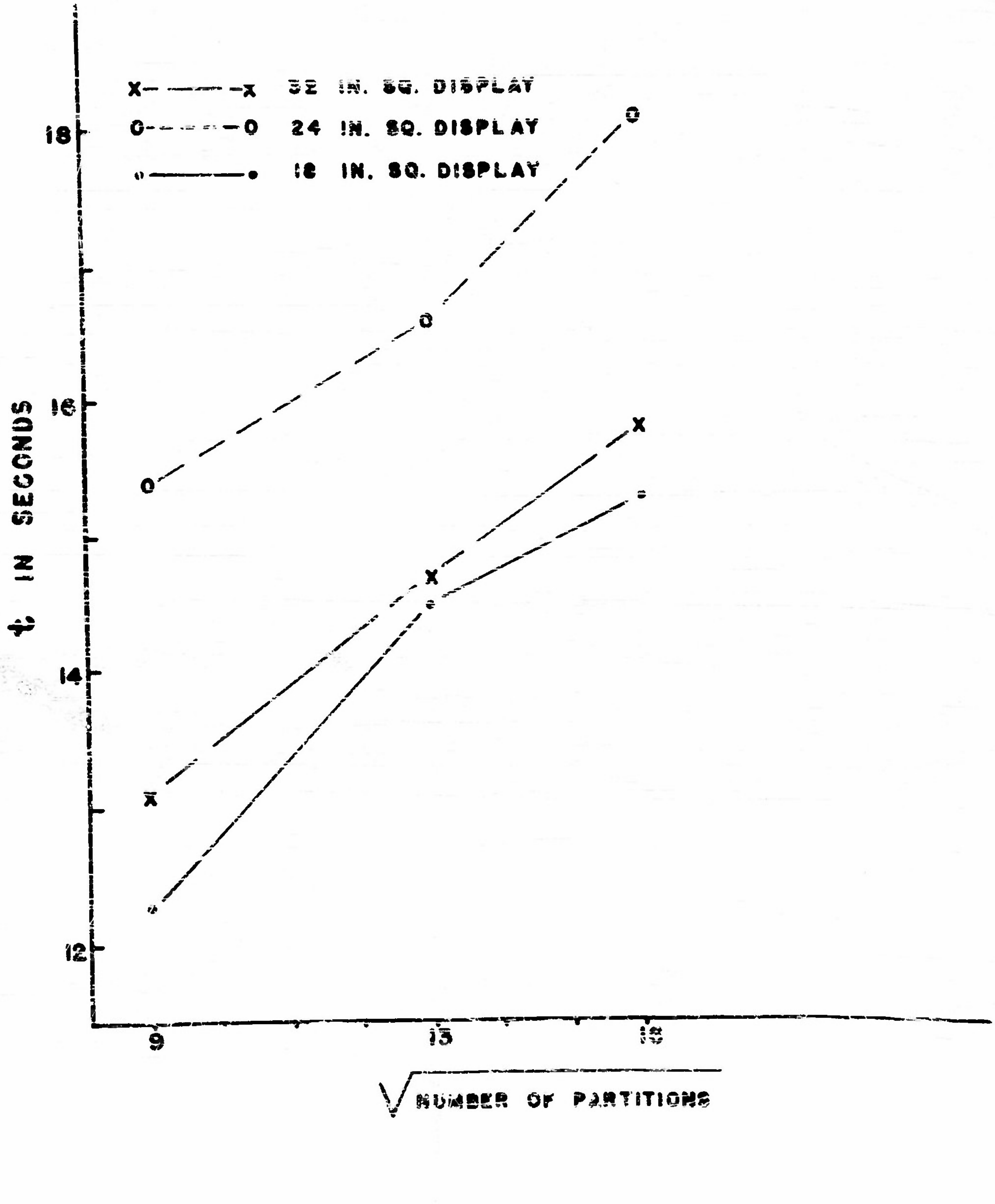


Figure 2. Search time as a function of display partitioning and area. Search time has been averaged through saturations and each point is the mean of 48 scores on each of 12 subjects.



IV. DISCUSSION

The results presented above can be briefly summarized as follows: (1) As the number of signals or objects in the display was increased, the time required for the visual location of a constant number of specific signals also increased; (2) when the visual field or display was partitioned into 81, 169, and 256 equal sectors by the use of grid lines, the speed of visual search decreased with the increase in the number of partitions; and (3) as the size of the display or search area was varied, it was found that visual search was most efficient when the search area was 18 and 32 in. square and least effective when 24 in. square.

The first of these findings agrees quite well with our intuitive expectations. It seems reasonable that it would be more difficult to locate a particular object or objects when the number of objects among which they were interspersed was increased. In the present case it would appear that this effect can be explained or understood in terms of the number of visual fixations required for the accomplishment of the task. Here the triangles were easily discriminable from the squares and diamonds as indicated by the fact that subjects rarely made an error by touching the stylus to the electrode beneath an incorrect signal. While peripheral vision is adequate for detecting the presence of a signal against the display field, it would appear that foveal vision was used or required to make the discrimination between target and non-target signals.3/ Detection by peripheral vision leads to a brief foveal fixation while the signal is identified as a target or non-target signal. If we take as the simplest case where only target signals are present in the display, only as many fixations as there are target signals is required. However, increasing the number of non-target signals in the display leads to more visual fixations. Every signal picked up in peripheral vision leads to a foveal fixation. Thus if search time is primarily dependent upon the time for fixation, increasing the number of objects in the display would be expected to lead to a linear increase in search time. Such a linear relationship was suggested by the obtained data.

Explanations for the effects obtained by increasing the number of partitions of the display are not readily apparent. The increase in search time with increases in the number of partitions has been shown in the present data to be due to the effect of the number of partitions *per se* and not to the absolute size of the separate divisions. It is possible that the presence of grid lines in the display has a distracting effect upon visual search. French (3) has shown that irrelevant signals in a display impede the recognition of target signals. He has termed this effect visual noise on the analogy of noise in an auditory system. However, labeling such effects as visual noise does not contribute to an understanding of the effects.

3/ While good form discrimination can be obtained in peripheral vision by training, it must be remembered that the present subjects were untrained. It also seems likely that even with training, if the task permits, foveal vision will be used for discriminations in preference to peripheral cues.

A likely explanation for the present data can be obtained if we examine how subjects approach the task of visual search and what use they make of grid lines. Grid lines in a display not only break the display up into cells and partitions, they also organize the display into columns and rows. This organization of the display may be expected to affect the subject's method of search. It would appear that subjects scan a display by either columns or rows when these are present in the display. Since increasing the number of partitions in a display results in an increase in the number of columns or rows that a subject must scan, a linear relation might be expected between the number of partitions and the speed of search. The data in Figure 2 do suggest such a linear relationship.

The findings in the present study with respect to search area may well be an artifact of the method the subjects were required to use to indicate that they had located a target signal. The slower search obtained for the 24 in. square display, as compared with the 18 and 32 in. square displays, may reflect a change in the perceptual-motor task. It was observed that subjects tended to use eye and head movements to scan the 18 and 24 in. displays, meanwhile holding the stylus in a fixed position. With the 32 in. display, subjects tended to move the stylus back and forth across the rows of the display in synchrony with their visual scanning. When the stylus is held in a fixed position, increasing the area of the display required longer movements in order to touch the electrode beneath the signal. However, when the area of the display becomes great enough, the shift over to a motor scanning again reduces the extent of the required movements once a target signal has been identified. Such an interpretation suggests that visual search, independent of the motor response necessary to signify location, is largely independent of the display areas used in the present experiment.

V. SUMMARY

The present study was concerned with the effect of several characteristics of visual displays upon speed of visual search. The time required to locate a constant number of signals in a square display was determined where (1) the number of irrelevant signals was varied from 10 to 70, and (2) when the number of partitions of the display was varied by the use of grid lines. Grid lines were used to partition the display into a 9 x 9, a 13 x 13, and a 16 x 16 matrix.

The results show that search time increases both when the number of irrelevant signals is increased and when the number of partitions is increased. An explanation was advanced for these effects in terms of the number of foveal fixations required for signal identification and the use that observers make of grid lines in their plan of search.

1. Eriksen, C. W. [illegible] complex [illegible]
Psychol. [illegible] 125-132.

2. Eriksen, C. W. Location of objects in a visual display [illegible]
the number of dimensions on which the objects differ. [illegible]
1952, 44, 56-60.

3. French, R. [illegible] Pattern recognition in the presence of [illegible]
exp. Psychol., 1954, 47, 27-32.

4. Lindquist, E. F. Design and analysis of experiments [illegible]
education. Houghton Mifflin: Boston, 1953.

5. Norton, D. W. An empirical investigation of some eff[illegible]
and heterogeneity on the F-distribution. Unpublished [illegible]
on file, State University of Iowa, 1952.

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